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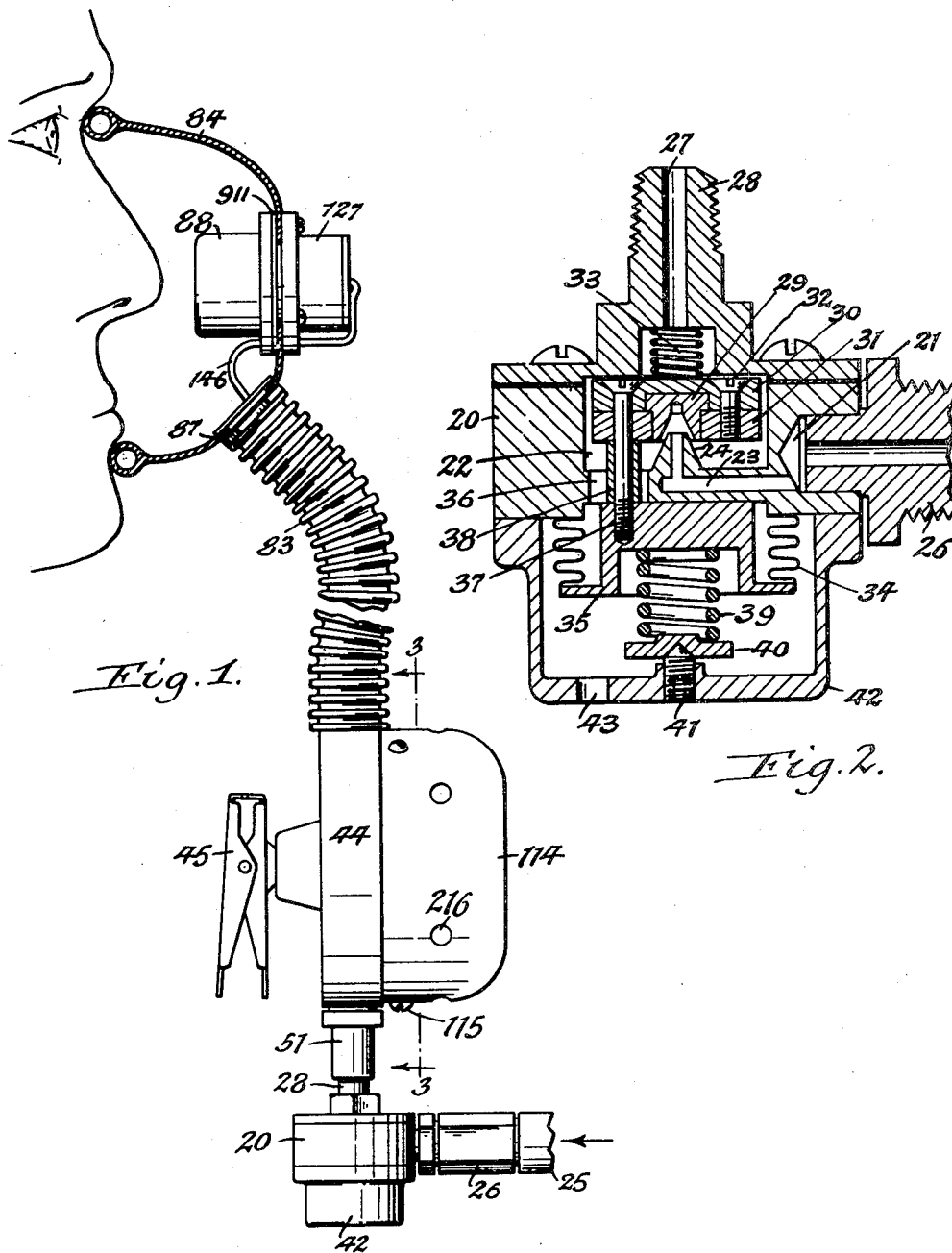
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2,452,670

BREATHING APPARATUS

Filed April 10, 1944

8 Sheets-Sheet 1



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Nov. 2, 1948.

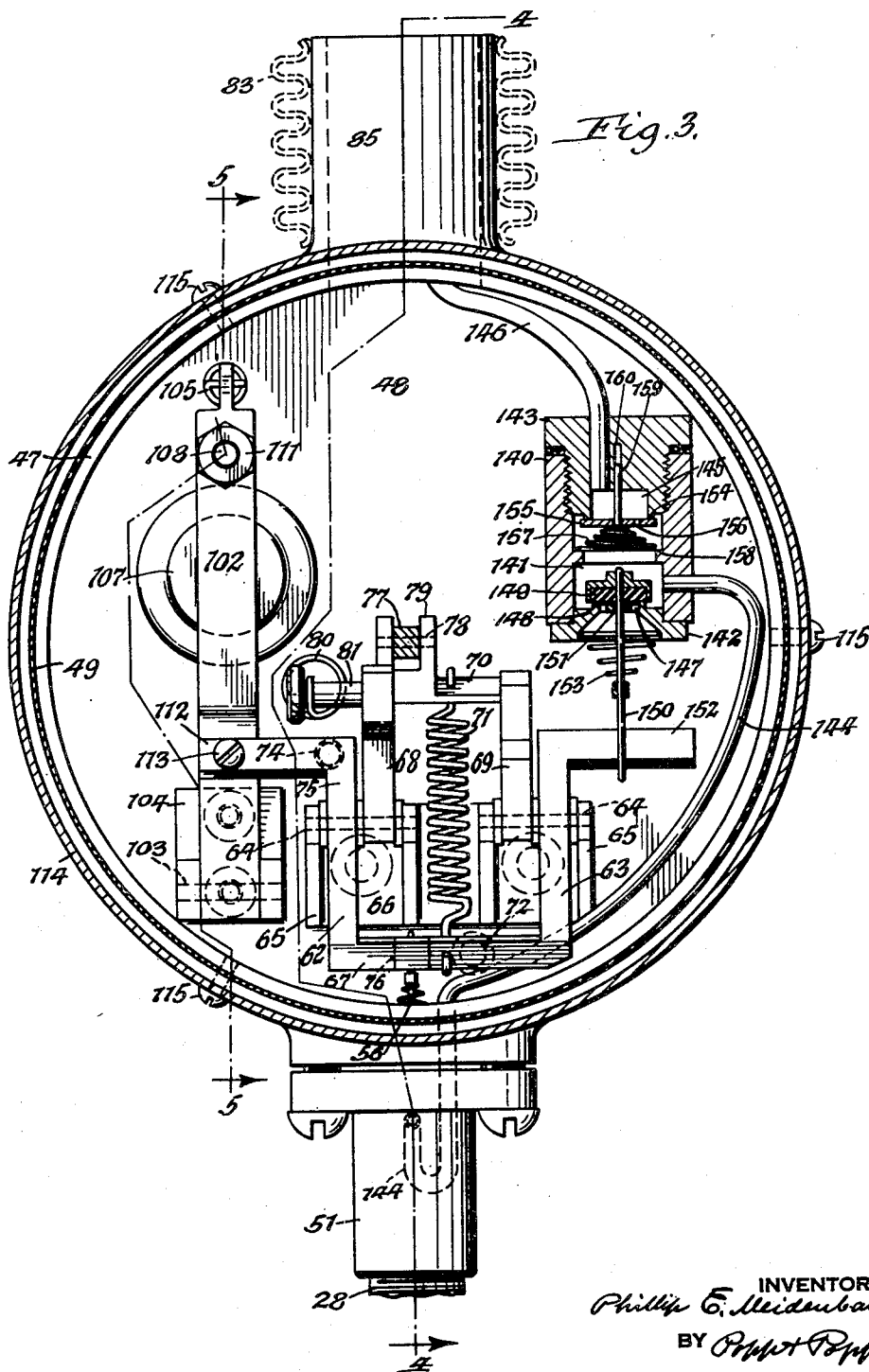
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BREATHING APPARATUS

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8 Sheets-Sheet 2



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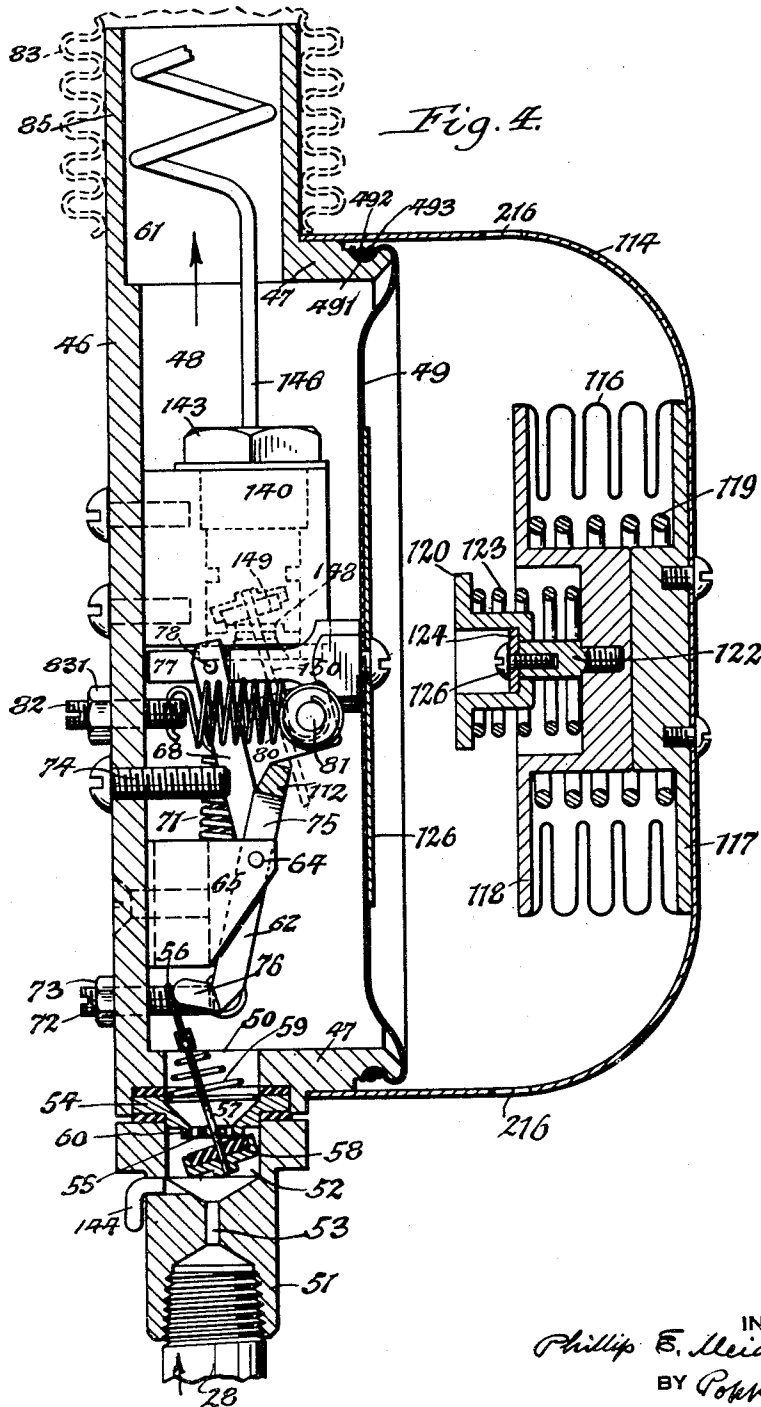
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8 Sheets-Sheet 3



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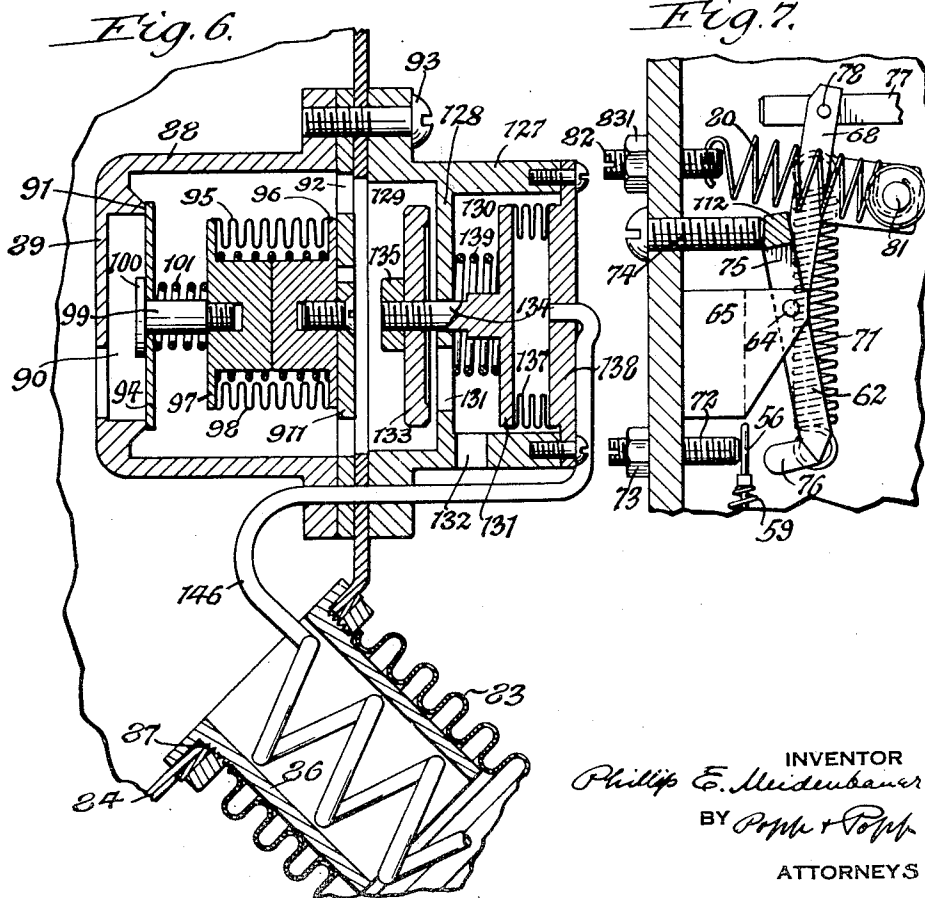
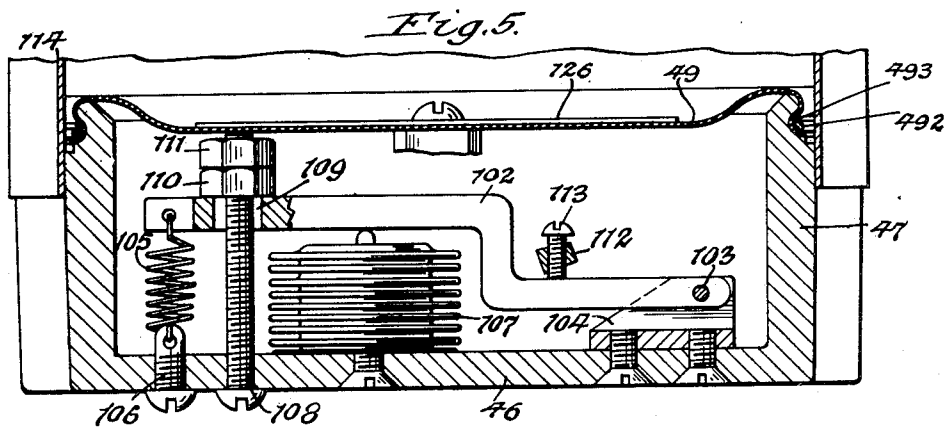
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8 Sheets-Sheet 4



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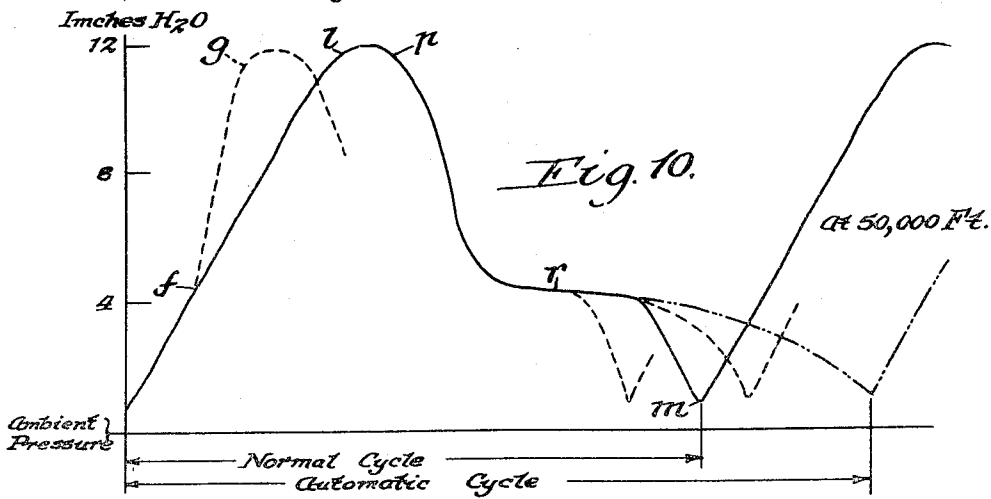
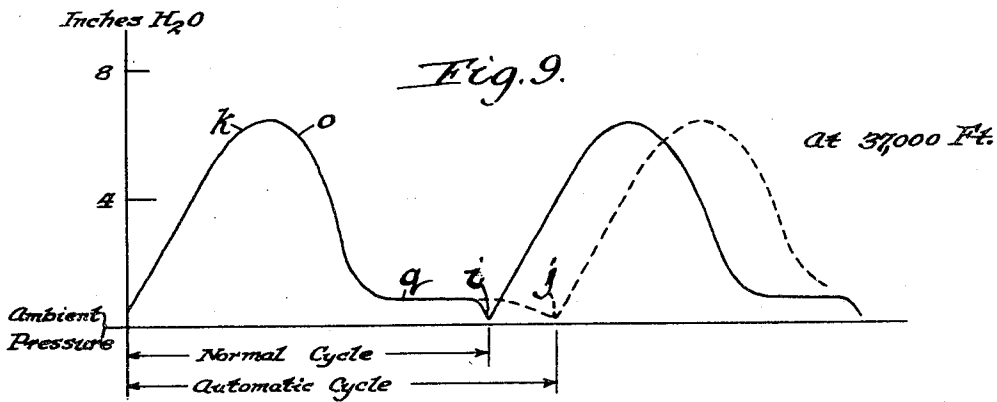
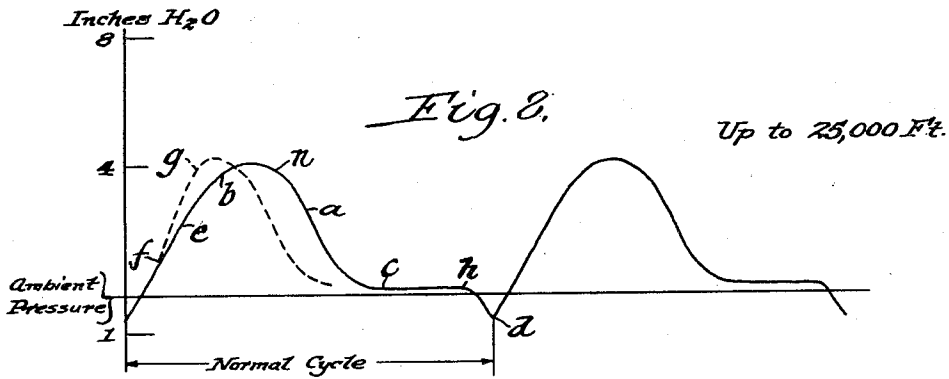
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8 Sheets-Sheet 5



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8 Sheets-Sheet 6

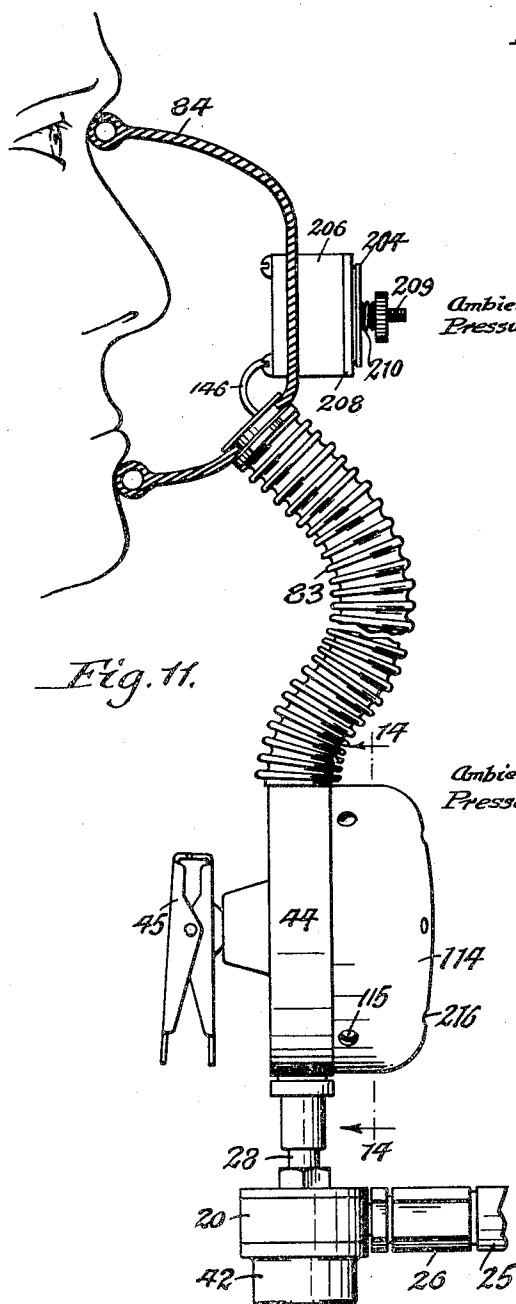
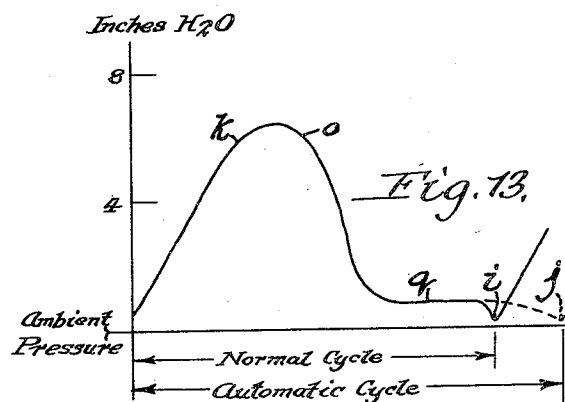
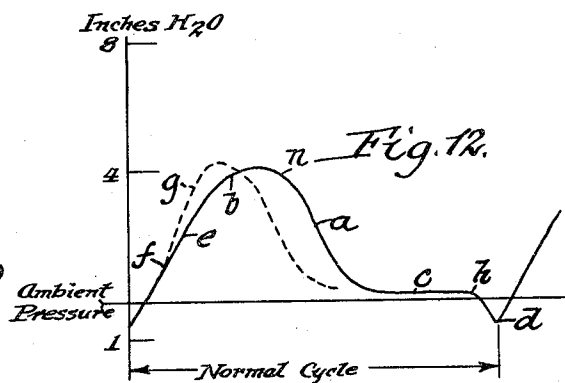


Fig. 11.



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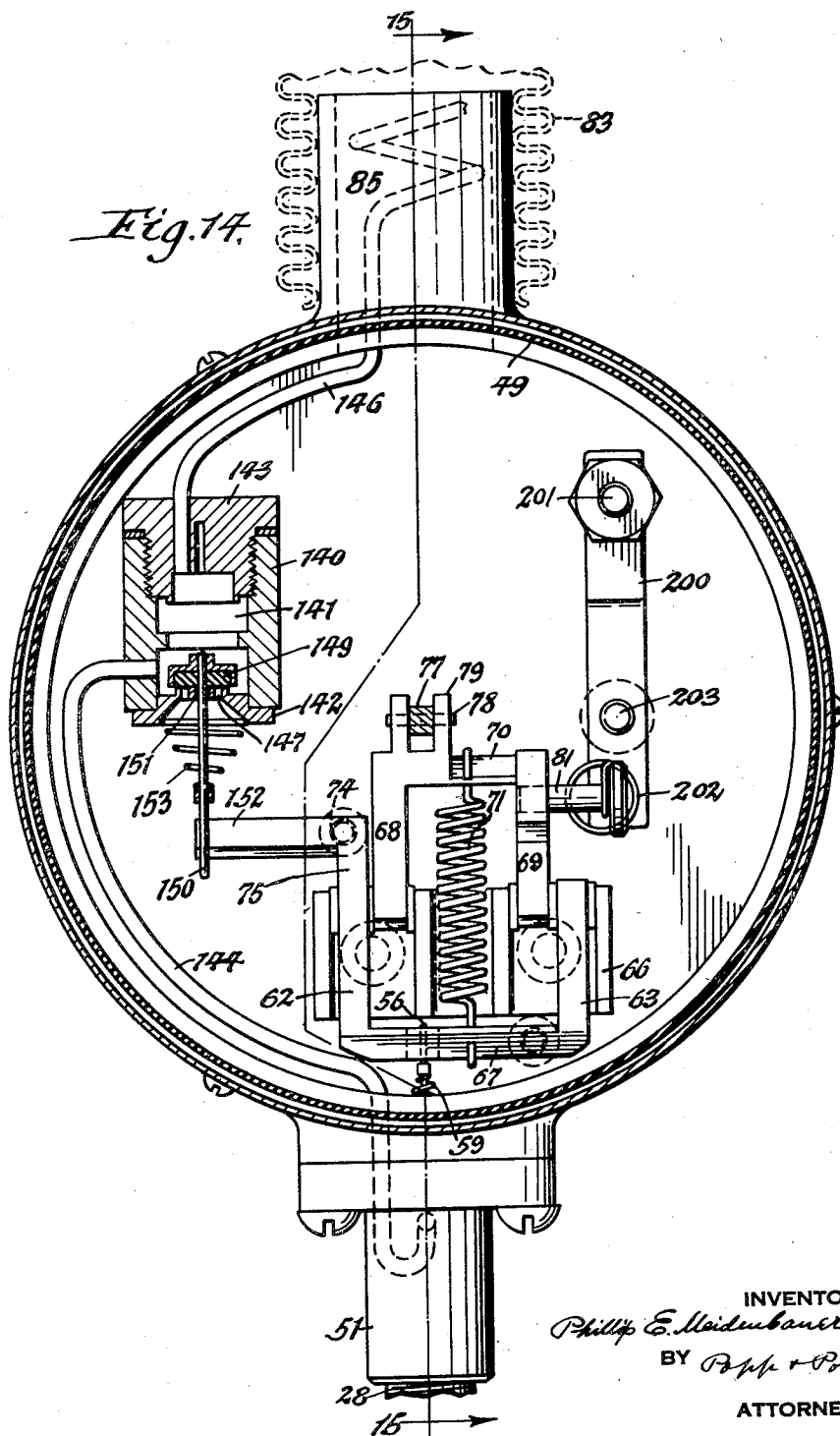
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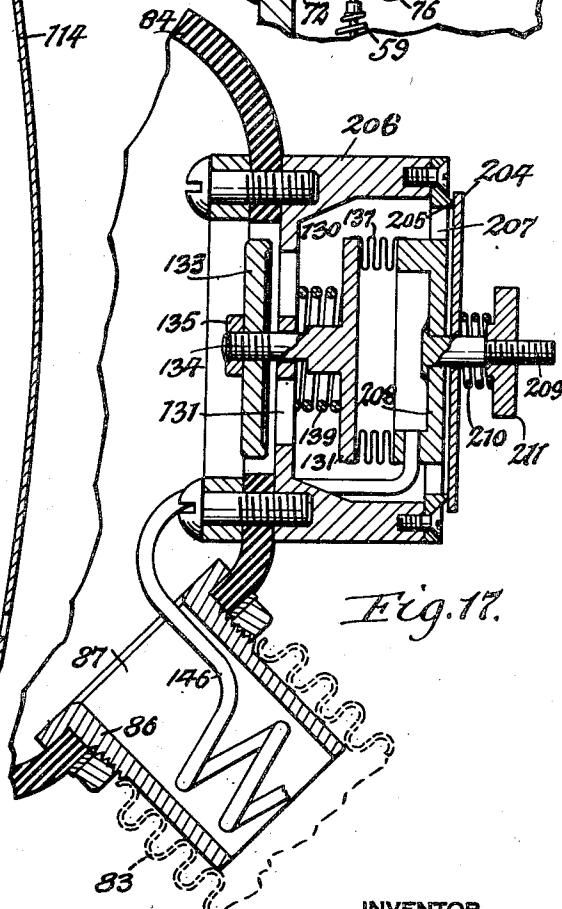
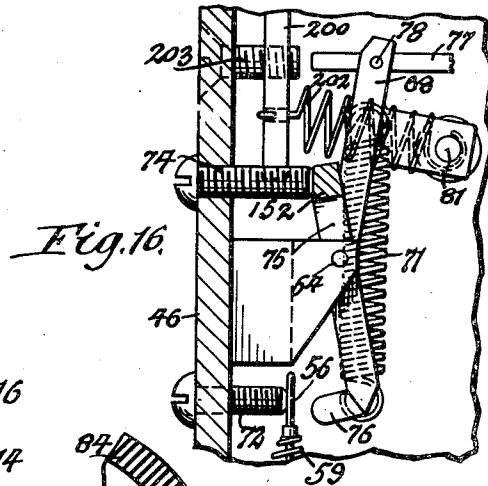
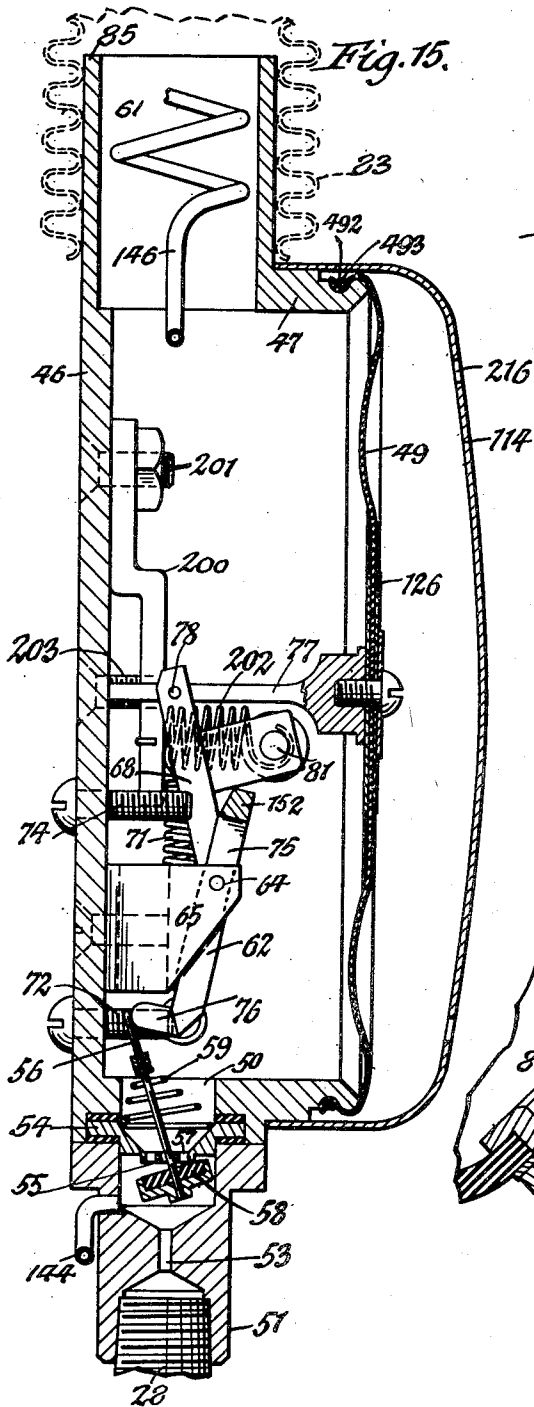
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BREATHING APPARATUS

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8 Sheets-Sheet 8



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UNITED STATES PATENT OFFICE

2,452,670

BREATHING APPARATUS

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Application April 10, 1944, Serial No. 530,262

27 Claims. (Cl. 128—142)

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This invention relates to a breathing apparatus which in an elaborate form is more particularly designed for use by aviators at high altitudes, although the same is also useful at low levels, and which in a simpler form is particularly useful at ground level for therapeutic purposes, such as treating pulmonary edema caused by war gases.

One of the objects of this invention is to provide an apparatus for this purpose which will operate efficiently and reliably to supply aviators with oxygen when flying at high altitudes either when he is conscious and able to help himself or when he is unconscious and unable to assist himself and wholly dependent on automatic operation of the apparatus for sustaining life.

Another object of this invention is to so organize the breathing apparatus that the same can be used for administering oxygen, medicated or other gases to patients at ground level for various ailments.

In the accompanying drawings:

Fig. 1 is a fragmentary side elevation, partly in section, of a breathing apparatus embodying a form of this invention which is more particularly designed for use by aviators when flying at high altitudes.

Fig. 2 is a vertical section of the pressure regulator whereby the gas which is received at high pressure from a supply source is reduced in pressure preparatory to being delivered to a person.

Fig. 3 is a vertical transverse section, on an enlarged scale, taken on line 3—3, Fig. 1, and showing the auxiliary oxygen supply valve open.

Fig. 4 is a vertical longitudinal section, taken on line 4—4, Fig. 3.

Fig. 5 is a fragmentary vertical longitudinal section, taken on line 5—5, Fig. 3.

Fig. 6 is a fragmentary vertical longitudinal section of the face mask and the exhalation valve mechanism associated therewith.

Fig. 7 is a fragmentary vertical longitudinal section similar to Fig. 4 but showing the snap action toggle mechanism which operates the main control valve in a different position.

Figs. 8, 9 and 10 are cards or diagrams indicating the cycle of operations of the apparatus at different altitudes.

Fig. 11 is a side elevation of a simpler form of apparatus embodying the essential features of this invention which are more particularly adapted for therapeutic uses.

Figs. 12 and 13 are cards or diagrams showing the operation of the apparatus shown in Fig. 11 under different conditions.

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Fig. 14 is a vertical transverse section, on an enlarged scale, taken on line 14—14, Fig. 11.

Fig. 15 is a vertical longitudinal section, taken on line 15—15, Fig. 14.

Fig. 16 is a fragmentary view similar to Fig. 15 but showing the snap-action toggle mechanism in a different position.

Fig. 17 is a fragmentary vertical longitudinal section, on an enlarged scale, of the face mask shown in Fig. 11 and the inhaling valve mechanism associated therewith.

In the following description like reference numerals indicate corresponding parts in the several figures of the drawings.

The general organization of the apparatus shown in Figs. 1—10 comprises a pressure regulator, a control mechanism whereby the gas is permitted to flow to or cut off from the face mask of the person, and an exhalation valve mechanism which controls the escape of the spent gas from the mask to the outer atmosphere.

Although the pressure regulator may be variously constructed, the same is preferably substantially like that shown in abandoned United States patent application Serial No. 508,946 which is as follows:

Referring to Figs. 1 and 2, the numeral 20 represents the body of the pressure regulator having a high pressure chamber 21, a lower pressure chamber 22 and a port or passage 23 leading from the high pressure chamber to the low pressure chamber and provided around its outlet within the lower pressure chamber with a valve seat 24. Oxygen under high pressure supplied from storage bottles or other source is delivered by a tube 25 and coupling sleeve 26 to the high pressure chamber. The lower pressure chamber is provided with an outlet 27 formed in a tubular neck 28 from which the gas is delivered to the means which control the supply of this gas to the person to be served.

Within the low pressure chamber is arranged a valve 29 which is movable toward and from the seat 24 for closing and opening the port 23 and which is mounted on a carrier having plates 30, 31 between which the valve is secured by one or more screws 32. A light balancing spring 33 interposed between the front side of the carrier and the regulator body serves to move the valve carrier rearwardly and assist the high pressure fluid in its closing effect on this valve.

In rear of the body is arranged a bellows diaphragm 34 having its inner end secured to the body while its outer end is connected with a head 35. The interior of this bellows and the low

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pressure chamber are connected by a passage 36 in the body and the bellows head and the valve carrier are connected by one or more screws 37 which latter are surrounded by spacing sleeves 38 interposed between the valve carrier and the bellows head.

The opening movement of the regulator valve 29 is effected by a heavy spring 39 interposed between the outer side of the bellows head and a follower 40 and the strength of this spring can be adjusted by an adjusting screw 41 engaging with the outer side of the follower and mounted on a casing 42. The latter is secured to the valve body and encloses the bellows and associated parts and provided with an opening 43 so as to expose the exterior of the bellows to atmospheric pressure. Before admitting fluid pressure into the low pressure chamber 22 the regulating valve is held open by the heavy spring 39 and the bellows is contracted, as shown in Fig. 2.

Upon admitting fluid under high pressure into the high pressure chamber 21 the same flows from this pressure chamber through the port 23 into the lower pressure chamber 21 and through the passage 36 and into the bellows 34. As the pressure in the bellows builds up the latter expands and pulls the regulating valve 29 rearwardly through the medium of the bellows head screw 37 and valve carrier, whereby the regulating valve is moved toward the seat 24 and the port 23 is reduced in effective area, thereby reducing the fluid pressure in the low pressure chamber accordingly. When the pressure in the low pressure chamber has reached a predetermined limit the valve 29 closes the port 23 completely and when the pressure in the low pressure chamber again drops below normal due to withdrawal of fluid therefrom, the resilience of the heavy control spring 39 causes the bellows to contract and open the regulating valve so as to resume the flow of fluid from the high pressure chamber to the low pressure chamber.

The control mechanism which receives the low pressure fluid from the pressure regulator and controls the delivery of the same to the person being served is shown in Figs. 1, 3, 4, 5 and 7 and constructed as follows:

The numeral 44 represents the body of the fluid control mechanism which is preferably supported while in use by means of a clasp 45 mounted on the rear side of this body and detachably connected with the front part of a harness worn on the body of the person using the apparatus so that it will be transported by and always available for this person.

The body of the control mechanism is constructed to form the fixed rear wall 46 and the fixed peripheral or side wall 47 of a main valve or respiration chamber 48 and the front wall 49 of this chamber is formed by a flexible diaphragm which extends across an opening in the front of the body and has its peripheral edge secured to the side wall of the body, as shown in Figs. 3 and 4, so that this diaphragm wall can collapse rearwardly or inwardly and expand forwardly or outwardly. Although this diaphragm may be secured to the casing or body in various ways this is preferably effected as follows:

The numeral 491 represents an annular groove formed on the exterior of the rim on the front side of the body. The marginal or edge portion of the diaphragm is placed on the case over the groove and an endless band 492 of rubber is placed around the outer side of the edge part of the diaphragm so as to draw the same inwardly into

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this groove. A string 493 is tied around that part of the diaphragm which has been drawn into the groove 491 by the rubber band 492, thereby firmly holding the diaphragm in place. In assembling these parts the diaphragm is first placed manually over the case and then the rubber band 492 snapped in place. Then the wrinkles are smoothed out, this operation being facilitated by the fact that the rubber band holds the diaphragm while the wrinkles are being slid outwardly beneath it. When the diaphragm is all smooth the string 493 is applied. In its lower part the side wall of the body containing the respiration chamber is provided with a fluid inlet 50 which is connected by a coupling tube 51 with the upper end of the outlet tube 28 of the pressure regulator for conducting fluid from the latter to the respiration chamber. The upper part of the bore of the coupling tube is comparatively large so as to form an inlet chamber 52 for an automatically controlled inlet valve mechanism and the lower part of this bore has the form of a small metered hole or orifice 53 whose function is to prevent fluid surges in the passage which connects the pressure regulator with the respiration chamber. By "metered" hole is meant, of course, that the apparatus is tested with different sized metering holes until the exact diameter of hole giving the best results has been ascertained and then this size of hole is adapted as standard equipment.

The passage connecting the pressure regulator and the respiration chamber is controlled by automatic valve mechanism which is constructed as follows:

The numeral 54 represents a valve plate or body which is secured between the valve tube 51 and the control body in such manner that the joints between the same are leak tight. In its central part this valve body or plate is provided with a guide opening 55 for a tiltable valve stem 56 which extends loosely through this guide opening, and a plurality of valve ports 57 which are arranged around this guide opening and are adapted to be uncovered or covered for placing the pressure regulator either in communication with the respiration chamber or cutting off communication between the same. This is accomplished by means which include a tiltable valve 58 arranged in the valve chamber 52 and secured to the lower end of the tiltable valve stem. The upper end of the latter is arranged within the fluid inlet 50 and the lower part of the respiration chamber 48 and the same is yieldingly pulled upwardly and held in its central position by a spring 59 preferably of conical helical form secured at its upper end to this valve stem and bearing at its lower end against an internal shoulder on the valve disk 54, as shown in Fig. 4. When the valve stem 56 is free the spring 58 turns the same into its central position in which the valve 57 is rocked into a position in which its plane is arranged at right angles to the axis of the valve disk 54 and engages the valve seat 60 on the underside of this valve disk so as to cover the valve ports 57 and the guide opening 55 and thereby prevent the flow of fluid from the regulator to the respiration chamber. Upon tipping the valve stem 56, the control valve 58 will be rocked so that a part thereof engaging with the valve seat 60 on one side of the axis of the latter will act as a fulcrum and that part of the same on the opposite side of this axis will move away from this valve seat, as shown in Fig. 4, thereby uncovering the ports 57 and guide opening 55 and

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permitting flow of fluid from the regulator into the respiration chamber.

Opening and closing of the fluid control valve 58 is effected automatically by means which are responsive to the admission of fluid into the respiration chamber through the inlet 50 in the lower part thereof and the discharge of fluid through the outlet 61 which is preferably arranged in the upper part of its side wall. In their preferred form these automatic control means include the diaphragm or wall as a pressure responsive element and are constructed as follows:

Within the lower part of the respiration chamber is arranged a toggle mechanism which includes lower and upper toggle levers which are adapted to rock relative to each other about an axis arranged transversely of the respiration chamber and part of the means for actuating the control valve 58 by motion derived from the diaphragm 49. The lower toggle lever is substantially U-shaped and comprises two parallel toggle arms 62, 63 pivoted at their upper ends by means of horizontal pivot pins 64 on bearing lugs 65 which form part of a base 66 secured to the back or rear wall 46 of the control mechanism body, and a lower cross bar 67 connecting the lower ends of these arms. The upper toggle lever is also of substantially U-shape and comprises two toggle arms 68, 69 arranged between the arms of the upper toggle lever and having their lower ends pivoted by the same pins 64 to said bearing lugs 65 while the upper ends of the upper toggle arms are connected by an upper cross bar 70. The numeral 71 represents a snap-action spring which is arranged lengthwise between the arms of the toggle levers and connected at its lower and upper ends, respectively, with the lower and upper toggle bars 67, 70, as shown in Fig. 3. Upon turning the toggle levers so that a line connecting the points at which the ends of the snap-spring 71 are attached to the toggle cross bars 67, 70 passes from one side of the axis 64 of these levers to the other thereof, this spring will be increasingly stretched upon approaching this axis and then contract upon moving away from this axis and quickly complete the folding action of the toggle levers in that direction and then yieldingly hold the toggle levers in a folded position on whichever side of said axis the toggle levers come to rest. The rearward folding movement of the toggle levers is arrested by a stop 72 which is adapted to be engaged by the rear side of the lower toggle cross bar at the end of the rearward folding movement of the toggle levers which stop is preferably adjustable and has the form of a screw engaging with a threaded opening in the rear wall 46 of the body and held in place after adjustment by a clamping nut 73 applied to this screw and engaging the outer side of this wall. The forward folding movement of the toggle levers is limited by a stop 74 which also preferably has the form of a screw secured in a threaded opening in the rear wall 46 of the body but does not require adjustment. This last mentioned stop 74 is engaged by a stop arm 75 projecting upwardly from the arm 62 of the lower toggle lever above the axis 64 of the latter. On its rear side the lower toggle cross bar 67 is provided with a rearwardly projecting trip finger or tappet 76 which is arranged in line with the valve stem 56. When the toggle levers are folded forwardly the trip finger 76 is moved forwardly away from the valve stem 56 and permits the spring 59 to close the valve 58 but when the toggle levers are folded inwardly this trip finger engages the valve stem

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56 and tilts the same rearwardly so that the valve 58 is tilted into an open position, as shown in Fig. 4, and thereby permits fluid under pressure to flow from the pressure regulator into the respiration chamber. The turning movement of the toggle levers is preferably so adjusted that forward folding action is arrested when the line between the points at which the snap spring 71 has reached the dead center or axis 64 of the toggle levers or has passed slightly forward of this center or axis, but the rearward folding movement of these levers is much greater in order to secure a slow or delayed closing of the control valve 58 and a quick or snap-action opening of the same.

Motion for turning of the toggle levers for folding the same either forwardly or rearwardly is effected mainly by expanding the diaphragm forwardly or contracting the same rearwardly in response to alternately admitting compressed fluid into the respiration chamber and exhausting the same therefrom. For this purpose the movement of the diaphragm is transmitted to the toggle levers by means of a shifting leg 77 which has its front end connected with the central part of the diaphragm and its inner part pivotally connected by a pin 78 with a shifting arm 79 on the upper toggle cross bar 70 while the rear end of this leg terminates close to the rear wall 46 of the control body.

In Fig. 4 the diaphragm has completed its rearward or collapsing movement and expelled a batch of fluid from the respiration chamber through its outlet 61 and the inlet valve 58 has been quickly opened to admit another batch of compressed fluid into this chamber. As the compressed fluid enters the respiration chamber the diaphragm is gradually moved forwardly and expanded by the fluid until this chamber has been filled as much as desired and during the initial part of this filling operation the toggle levers are gradually unfolded from their rearmost position and the snap-spring 71 is increasingly strained until it is at least in line with or somewhat forwardly beyond the dead center 64 at which point the resilience of the snap-spring 71 completes the outward folding movement of the toggle levers and the expansion of the diaphragm and quickly closes the control valve 58 for arresting the further entrance of compressed fluid into the respiration chamber.

Rearward or collapsing movement of the diaphragm for expelling the fluid from the respiration chamber, while the inlet valve is closed, is effected by the suction or inhalation of the person being served while breathing when he is conscious, which suction is aided by expelling means which are strained as the diaphragm is expanded and subsequently assist in again collapsing the diaphragm. These expelling means preferably comprise an expelling spring 80 which has its front end connected with a pin 81 on the upper toggle lever while its rear end is connected with an adjusting screw 82 which works in a threaded opening in the rear body wall 46 and is held in place by a clamping screw nut 83 applied to this screw and engaging the outer side of this wall, as shown in Fig. 4. This expelling spring also serves to resist the expanding action of the diaphragm and cause pressure to be built up in the fluid in the respiration chamber for aiding in its delivery from this chamber, which pressure can be adjusted by means of the adjusting screw 82.

From the outlet of the respiration chamber

the gaseous fluid is delivered by a flexible or corrugated rubber hose 83 to a mask 84 applied to the face of the person being served which mask may be of any suitable construction and preferably constructed so as to cover the mouth and nostrils, as shown in Fig. 11. The connection between the hose and the outlet of the respiration chamber is preferably effected by securing the lower end of this hose around an outlet tube 85 which is formed on the side wall 47 around the outlet 61 and the upper end of this tube is secured around an inlet tube 86 which is fastened to the face mask within a fluid inlet opening 87 on the lower part of the mask, as shown in Fig. 6. During automatic operation of the control mechanism in the respiration chamber and also by inhalation of the person being served, when he is conscious, oxygen or other gaseous fluid is drawn from this chamber into the mask and during exhalation by this person the spent fluid is discharged to the outer atmosphere by a discharge valve mechanism which includes the following:

Within the mask is arranged a discharge valve case having a tubular body 88, a fixed head 89 at the inner side of the body provided with a port 90 and an outwardly facing valve seat 91, and an outer detachable head 911 provided with ports 92 adjacent to the body 88. The detachable head and the body of the discharge valve case are secured to the inner side of the front part of the mask by screws 93 which also serve to fasten other parts to the mask as will later appear. The numeral 94 represents an exhalation or discharge valve which is arranged within the inner part of the discharge valve casing and which preferably is made of metal and has the form of a disk and is movable into and out of engagement with the valve seat 90 for closing and opening the exhalation port 89. This exhalation valve is associated with control means whereby this valve will close when the person using the apparatus is inhaling fresh fluid but will open when exhaling spent fluid, the control means being so constructed that the effort required to open the valve will vary according to the ambient air pressure of the altitude at which the breathing apparatus is being used. The control means for this purpose shown in Fig. 6 are constructed as follows:

The numeral 95 represents the flexible bellows or corrugated body of an aneroid, 96 its outer head which is secured to the inner side of the outer head 91 of the valve casing and 97 the inner head which is secured to the inner end of this body and forms with the same and the outer head 96 a hermetically sealed box from which the air has been partially exhausted. The interior of this aneroid box is provided with the usual compression spring 98 which resists contraction of the bellows body thereof and this contraction is preferably limited by engagement of the opposing sides of the heads 96, 97, as shown in Fig. 6. The numeral 99 represents the body of a screw which forms a valve stem which is secured with its outer threaded end to the central part of the inner aneroid head 97, while its inner part engages slidably with an opening in the central part of the exhalation valve and its inner end is provided with a head 100 which engages with the inner side of the valve 94. A spring 101 surrounds the valve stem 99 and bears at its opposite ends against the inner side of the valve 94 while its outer end bears against the inner aneroid head 97.

While flying at comparatively low altitudes the heads of the aneroid are in engagement and form a solid abutment with each other, as shown in

Fig. 6, so that the exhalation valve 94 is moved outwardly into an open position and permits the exhalation to escape, during which time the opening of this valve is only opposed by the spring 101 which at this time exerts the least resistance to the opening of this valve. When flying at medium altitudes where the atmosphere is somewhat rarified the bellows wall or body of the aneroid is expanded and the inner head 97 of the same is moved inwardly to some extent, thereby compressing the spring 101 to a greater extent and causing the same to exert greater resistance to the opening of the valve 94 and thus require greater exhalation before this valve will open to permit the spent exhalation fluid to escape. When flying at extremely high altitudes the inner end or head of the exhalation valve stem engages with the inner head or spider 89 of the exhalation valve case which head acts as a stop to prevent the increased rarification of the atmosphere in these altitudes from further increasing the compression of the spring 101 and the increased resistance which the same would otherwise offer to the opening of the exhalation valve 94. It has been calculated that the heads of the aneroid will remain in engagement with each other so that the aneroid will not affect the compression of the spring 101 up to an altitude of 30,000 feet but the aneroid will operate and put this spring under increased compression and thus increase the resistance to the opening of the exhalation valve up to an altitude of 45,000 feet at which time the valve stem 99 will engage the stop 89 and prevent further compression of this spring. The reason for limiting the expansion of the aneroid is that ordinarily the expansion of the aneroid is directly proportional to the elevation of the flying machine but the human breathing requirements as to the back pressure on the exhalation valve are not directly proportional to elevation in that it is not desirable to have any material increase of back pressure on the exhalation valve above an altitude of 45,000 feet. The present organization therefore is such that at levels up to 30,000 feet the spring 101 will offer a relatively low resistance to the opening of the exhalation valve, while flying at an altitude of 30,000 to 45,000 feet the resistance to the opening of the exhalation valve will be increased, at altitudes above 45,000 feet the aneroid is prevented from further increasing the resistance to the opening of this valve.

It is extremely important that when the aviator is flying at an altitude of approximately 37,000 feet the oxygen supplied to him by this apparatus is not diluted with air and this is ensured in accordance with the present invention by means which maintain the pressure in the mask always above ambient pressure as follows:

As shown in Figs. 3 and 5, the numeral 102 represents an aneroid lever arranged in the respiration chamber and pivoted at one of its ends by a pin 103 on a bracket 104 secured to the inner side of the back wall 46 of the respiration chamber, while its opposite end is yieldingly drawn toward this wall by a spring 105 which has its inner end connected with the free end of the lever 102 while its outer end is connected with a screw 106 secured in an opening in said back wall. Intermediate of its ends this aneroid lever 102 bears with its outer side against the inner movable end of an aneroid 107 which has its outer end secured to the inner side of the adjacent part of the back wall 46. This aneroid is of substantially the same construction as that shown in Fig. 6. Expansion of this

aneroid is adjustably limited by stop means consisting preferably of a stop bolt 108 having its outer end secured to the wall 46 and its inner end arranged in an opening 109 in the free end of the aneroid lever 102, a stop screw nut 110 adjustable on the inner end of the aneroid lever and engaged by the inner side of this lever, and a clamping screw 111 arranged on the adjusting bolt and holding the stop screw nut 110 in its adjusted position.

The lower toggle lever is provided on its arm 62 with a lug 112 projecting laterally outward from the stop arm 75, which arm and lever together form a cantilever which is connected with the toggle arm 62 and projects upwardly from the axis 64 of this toggle arm. The lug 112 is provided with an adjustable bearing point 113 which engages with the inner side of the aneroid lever 102 and preferably has the form of a screw engaging with a threaded opening in this lever. This aneroid 107 is responsive to the ambient pressure at different altitudes and operates through the medium of the parts which operatively connect the same with the toggle mechanism to provide a negative minimum pressure at low altitudes in the respiration chamber and the spaces communicating therewith, and a positive minimum pressure therein at higher altitudes.

Automatic control means are provided for causing oxygen to be admitted to the respiration chamber in accordance with the altitude at which the aviator is flying which means are best shown in Figs. 1 and 4 and constructed as follows:

The numeral 114 represents a dish-shaped cover arranged outside of the diaphragm 49 and having its edge secured around the adjacent part of the body side wall 47 by screws 115 or otherwise while the peripheral part is provided with openings 216 for maintaining atmospheric pressure within this cover. Within this cover is arranged an aneroid comprising a flexible corrugated or bellows body 116, an outer head 117 secured to the outer end of the bellows and mounted on the central part of the inner side of the cover, and an inner head 118 secured to the inner end of the bellows and adapted to engage the outer head of this bellows in the contracted condition of the latter, thereby forming a hermetically sealed box or chamber from which the air has been partially exhausted. Within this box is arranged a compressed spring 119 bearing at its ends against the heads 117 and 118 which assists in expanding this aneroid when the atmosphere becomes rarified in the higher altitudes instead of relying on the resilience of the bellows body 116 to push the inner head 118 longitudinally inward against the external ambient atmospheric pressure.

The numeral 120 represents a buffer which has the form of a hollow or cup-shaped foot and is out of engagement from the diaphragm when the latter is contracted but which in the fully expanded condition of the diaphragm is engaged by the latter and resists the final part of its expansion for the purpose of building up pressure in the respiration chamber. This buffer is preferably constructed in the form of a cup which is arranged within the cover 114 at the inner end of the aneroid therein and is provided in the center of its bottom with an opening 121 which receives the inner part of a guide post 122 projecting inwardly from the inner head 118 of the aneroid bellows 116. The numeral 123 represents a helical spring which surrounds the guide post 122 and is interposed between the buffer and the inner head of the aneroid bellows 116 and operates to

yieldingly hold the buffer at a distance from the inner end of this aneroid. This movement of the respective aneroid is limited by stop means consisting preferably of a washer 124 engaging the inner side of the post 122 and secured to the inner end of this post by a screw 125, as shown in Fig. 4. The spring 123 permits a certain amount of movement of the diaphragm after the disk 126 on the outer side of the same has contacted the buffer. If the spring 123 were not used a delicate adjustment of the buffer 120 relative to the diaphragm would be necessary in order to avoid bringing the diaphragm to a sudden stop when arresting its expansion movement and as a consequence the toggle mechanism would not be actuated unless the diaphragm shifted the toggle levers into their foremost position before the diaphragm contacted this aneroid. From this it will be evident that this aneroid would be useless unless it is permitted to perform its function of automatically varying the time of tripping the toggle mechanism for stopping the flow of oxygen into the respiration chamber through its inlet 50 in accordance with the altitude at which the aviator is flying, that is to say, at low altitudes the aneroid 116 will contract and cause the admission of oxygen to be cut off earlier and at high altitudes this aneroid will expand and cause the admission of oxygen into the respiration chamber to be cut off later.

During normal breathing a person expands the diaphragm and ribs of his chest and "sucks in" fresh oxygen loaded air. At the end of the inhalation, when the positive pressure in the lungs is at its maximum, a normal person usually pauses for a moment before allowing the muscles of the chest to relax and thus prevent lowering of the pressure in the lungs so rapidly as would provide insufficient time for permitting the osmosis operation in the lungs to be effected. In accordance with the present invention the oxygen is forced positively into the aviator's lungs but when the pressure reaches a predetermined maximum it is not allowed to fall too rapidly. This is accomplished by a retarding valve mechanism which prevents the pressure of the fluid in the respiration compartment, the mask and the hose connecting the same, upon reaching its maximum, from dropping too rapidly and thus allow ample time for the lungs of the person using the apparatus to perform their osmotic function of absorbing adequate oxygen. The preferred form of this retarding valve mechanism is shown in Figs. 3, 4 and 6 and is constructed as follows:

The numeral 127 represents a retarding valve case which is secured by the screws 93 to the outer side of the mask 84 in line with the exhalation valve mechanism and which contains a partition 128 whereby the interior of this case is divided into an inner or rear chamber 129 and an outer or front chamber 130. These chambers communicate with each other through a regulatable retarding port 131 in this partition and the inner chamber is constantly in communication with the exhalation valve chamber 88 through the openings 92 and the front chamber 130 is in constant communication with the outer atmosphere through an opening 132. Within the inner chamber 129 is arranged a control or retarding valve 133, preferably of disk form which is movable lengthwise toward and from the valve port 131 for the purpose of covering and uncovering the same more or less and thus varying the rapidity of flow of the spent fluid

from exhalation valve mechanism to the atmosphere. The retarding valve 133 is adjustably mounted on a longitudinally movable valve stem 134 which slides in a guide opening in the partition and provided with a thread on its inner part which engages a threaded opening in the center of the valve 133. After adjusting the retarding valve into the desired position on the stem it is held in place by a clamping screw nut 135 on the inner part of this stem and engaging the inner side of this valve, as shown in Fig. 6. At its outer or front end the valve stem 134 is connected with a head 136 on the inner end of a diaphragm 137 which is preferably of bellows form and has its outer end secured to the outer wall or head 138 of the chamber 130. Collapsing of the bellows diaphragm 137 is effected by a spring 139 which is interposed between the partition 128 and the inner head 132 and tends constantly to push the latter outwardly.

Within the respiration chamber is arranged an auxiliary valve mechanism which controls the spent fluid retarding mechanism and which operates in harmony with the toggle mechanism whereby admission of oxygen to the apparatus is controlled. This auxiliary valve mechanism in its preferred form is constructed as follows and shown in Figs. 3, 4, and 6:

On the rear wall 46 of the respiration chamber is mounted the casing of the auxiliary valve mechanism which preferably comprises a longitudinal body 140 containing an auxiliary valve chamber 141 which is provided at its lower and upper ends with heads 142, 143. The lower part of the valve chamber 141 communicates constantly with the fluid inlet valve chamber 52 below or in advance of the main tilt valve 58 by means of an inlet or tube 144. The upper head 143 is provided on its inner end with a port 145 which communicates with the interior of the retarding bellows 137 by means of a tube 146 which has a part of its length made of helical form and arranged in the corrugated oxygen or fluid hose 83. The tubes 144 and 146 are made of comparatively small diameter which together with the helical form of the tube 146 causes the same due to frictional resistance and capillary action, to retard the flow of oxygen therethrough and thus delay transmission of fluid pressure from the inlet chamber 52 and the respiration chamber 48 to the retarding bellows 137, for a purpose which will be presently explained.

The lower head 142 of the auxiliary valve chamber 141 is provided with an annular row of ports or openings 147 and a rearwardly facing valve seat 148 on the inner side of this head around these ports. These ports are covered and uncovered by an auxiliary tiltable oxygen inlet valve 149 arranged within the lower part of the auxiliary chamber 141 and adapted to either engage the valve seat 148 over its entire area, as shown in Fig. 3, and thus close the ports 147 and prevent the passage of oxygen or fluid from the respiration chamber into the transfer chamber, or to engage only part of this valve seat by tilting relative to the same and thus uncover these ports and permit oxygen to flow from the respiration chamber 48 into the auxiliary chamber 141. Opening of the auxiliary valve 149 is effected by motion derived from the toggle mechanism and closing of the same is effected by spring return means. For this purpose the auxiliary valve is connected with the inner end of a valve stem 150 which is adapted to rock in a

guide opening 151 in the center of the casing head 142 and has its outer end overlying a cantilever arm 152 of angular form which is connected with the arm 63 of the lower toggle lever and projects from the opposite side of the axis 64, as shown in Fig. 3. Whenever the toggle mechanism operates to open the main oxygen inlet valve 58 then the cantilever arm 152 moves the valve stem from its central normal position, in which the valve 149 is closed, to a tilted position in which this valve is opened. This valve is yieldingly held in its closed position by a spring 153 interposed between the stem of this valve and the casing head 142 on which this stem rocks so that this spring is deflected when this valve is opened by the rearward folding action of the toggle mechanism and the forward throw of the cantilever arm 152 but when the latter is moved rearwardly during the forward folding action of the toggle mechanism the resilience of the spring 153 returns the auxiliary valve 149 to its closed position in substantially the same manner in which the main inlet valve 58 is opened and closed.

The inner end of the port 145 is surrounded by a forwardly facing valve seat 154 which is adapted to be engaged and disengaged by a light check valve 155 of metal which has a leak or bleed opening 156. This valve is yieldingly held in its closed position by a spring 157 interposed between the same and a shoulder 158 on the inner side of the casing body 140 and this valve is guided in its movements toward and from its valve seat 154 by a guide stem 159 secured at one end to this spring 157 and sliding at its opposite end in an opening 160 in the upper casing head 143, as shown in Fig. 3.

As the aviator exhales the control valve 133 opens slowly, but closes rapidly when he inhales so as to prevent the higher than ambient pressure which is being built up in the mask from escaping through the loaded exhalation valve 94. This result is due to the opening of the main tilt valve 58 and the auxiliary tilt valve 149 whereby the pressure previously stored in the mask bellows 137 quickly passes out through the flexible tube 146 and past the check valve 155 into the auxiliary valve chamber 141 and through the open auxiliary tilt valve 149 into the main respiration chamber 48. It is true that, at this time, oxygen under pressure is being fed into the respiration chamber through the open main tilt valve 58, but this is immaterial because it takes some time for this pressure to build up in the respiration chamber and the pressure in the latter at no time even remotely approaches the pressure at the main gas inlet 52 before it is reduced to permit of its use in this apparatus. Moreover the main inlet valve 58 is closed before a very high pressure can be built up in the respiration compartment 48.

The relatively high fluid pressure in the inlet 52 of the apparatus is utilized, upon opening the main valve 58, to expand the bellows 137 on the mask due to the following action:

Upon commencing an exhalation the tilt valves 58 and 149 are both closed by the toggle mechanism and oxygen at relatively high pressure is conducted from the high pressure inlet 52 through the tube 144 into the auxiliary valve compartment 141. As the auxiliary tilt valve 149 is closed during this exhalation period and the metal check valve 155 is also closed, it is only possible for this relatively high pressure oxygen to flow slowly through the leak opening 156 in this check valve 155 and pass through the upper flexible tube 146

into the bellows 137 and inflate the latter. This inflation is relatively slow due to the resistance to backward flow of oxygen through the check valve and the friction and capillary action of the tubes 146 and 144 which are of relatively small internal diameters. This results in the control valve 133 opening slowly at the beginning of the exhalation period and then preventing the lungs from too rapidly discharging the spent fluid which they had just received during the previous inhalation period.

In accordance with this operation of the apparatus oxygen will be forced into the lungs of the aviator from ground level up to an altitude of 25,000 feet which forcing after it has commenced is fully automatic, except that the aviator can exhale whenever he desires to do so, but when exhaling he must first get the pressure in the mask up to the normal maximum inhalation pressure before the spent air can be vented from the mask. At this range of elevation and up to an altitude of 30,000 feet the aviator has complete control of the beginning of the inhalation period because a negative pressure is required to flip the toggle mechanism and the valves operated thereby into an open position.

At higher elevations the matter of leakage of air into the mask becomes vital and hence the instrument, because of the use of the aneroid 107 and associated mechanism, requires a small minimum positive pressure to start the inhalation period. This means that the pressure in the mask is always positive at these higher elevations and any leakage of the mask can only be outward and not inward. Concomitantly the instrument becomes automatic to the extent that if the aviator "blacks out" the instrument will effect automatic breathing for the aviator. Nevertheless, if the aviator is conscious, he has considerable control over the beginning of his inhalation and exhalation cycles, but he is incapable of changing the maximum and minimum pressures, which minimum positive pressure cannot be increased above an altitude of 37,000 feet due to stop nut 110 which limits the expansion of the aneroid 107 at high altitudes.

At all elevations the control valve 133 so operates that the aviator's lungs are subjected to substantially maximum pressure for an appreciable length of time after the beginning of each exhalation period so that a reasonable length of time is afforded for the osmotic exchange in the lungs of oxygen and carbon dioxide. To compensate for the lower ambient pressure at high elevations both the maximum pressures are raised, the aneroid 116 operating to raise the maximum pressure during inhalation and the aneroid raising the pressure during exhalation, but at an elevation of 45,000 feet further movement of the aneroid 98 is prevented by its head 100 striking the inner face of the spider or wall 89.

It will be apparent that in using this apparatus the aviator has almost complete control of his breathing cycles. On inhalation however he cannot prevent the building up of pressure but he can start exhaling any time he desires and due to a negative pressure being required before the main oxygen valve 58 will open it is evident that the apparatus is not automatic as to starting the inhalation period. This therefore operates to prevent "over ventilation" as previously explained.

From the foregoing it will be apparent that by the use of the exhalation valve 94 which is sub-

ject to the influence of the aneroid 98 responsive to altitude, and the control valve 133 which is subject to the action of the bellows 137 by pressure derived from the main pressure source that the control valve will be closed slowly at the start of the exhalation cycle and that the control valve will be closed instantly by means of the spring 139 when the pressure in the bellows 137 drops below normal, thereby preventing gas from leaking outwardly past the exhalation valve 94 even though the pressure in the mask becomes higher than that which would open the exhalation valve if the control valve were absent.

Inasmuch as the exhalation valve 94 is arranged close to the aviator's face the warmth of the latter prevents this valve from freezing and becoming inoperative but this is not liable to occur to the control valve 133, notwithstanding the same is exposed to a greater extent to the atmosphere because the means for actuating the same by power derived from the pressure in the main or respiration chamber are sufficiently powerful to overcome the effects of frost or low temperature.

It is to be noted that owing to the location of the inhalation valve 94 and associated parts on the inside of the mask the same are not likely to become inoperative due to freezing when the aviator is flying at extremely high altitudes.

From the foregoing it will be apparent that this breathing apparatus will operate wholly automatically for supplying oxygen to a person who is unconscious and unable to aid himself and will also cooperate with a person who is sufficiently conscious to assist this apparatus in supplying oxygen.

The sequence of the several steps in the complete operation of the breathing apparatus shown in Figs. 1-7 and indicated on the charts or graphs shown in Figs. 8, 9 and 10 as follows:

Pure oxygen is supplied at high pressure, say 1,000 pounds per square inch, from a suitable tank, bottle, or elsewhere and fed to the inlet 21 of the pressure regulator which reduces the pressure of the oxygen to say 40 pounds per square inch and delivers the same at this pressure to the inlet side 52 of the valve 58 which controls the flow of the fluid through the inlet 50 into the respiration chamber 48 of the automatic control mechanism. The control valve 58 is opened by the toggle actuating mechanism during the last part of the rearward or contracting movement of the diaphragm 49 and closed during the last part of the forward or expanding movement of the same. The screw 72 permits of effecting a fine adjustment of the maximum pressure which may be built up in the respiration chamber 48 before the admission of further oxygen into this chamber is cut off. From the respiration chamber the oxygen passes through the outlet 61 thereof into the corrugated tube 83 and delivered by the latter into the face mask where it is inhaled by the aviator. Upon exhalation of the aviator the spent fluid is discharged past the exhalation valve 94 to the outer atmosphere. Owing to the large size of the hose or tube 83 the pressure within the respiration chamber and within the face mask is always substantially the same.

Let it be assumed that the aviator has previously received and inhaled oxygen under pressure and is now exhaling foul air into the mask from which it flows past the loaded exhalation check valve 94 and past the retarding valve 133 to the outer atmosphere. As he continues to exhale, and, concomitantly the volume of air in his lungs becomes increasingly depleted and consequently

the lung actuating muscles become relaxed, the pressure in the face mask and in the respiration compartment 48 will drop comparatively rapidly, as indicated by the curve *a* on the graph Fig. 8 from the high level *b* and level off to a small positive pressure *c*. At ground level and up to an altitude of 30,000 feet, this small positive pressure at *b* persists indefinitely until the aviator starts to inhale again, thereby preventing the aviator from getting more oxygen than he needs, in other words, it prevents what is commonly termed "over-ventilation." By maintaining this negative pressure at this time he is prevented from being inflated until he inhales and then only gets a "shot" of oxygen when he wants it, this being caused by the negative pressure resulting from his inhalation. This inhalation drops the pressure in the mask and in the respiration compartment 48 to a point below the ambient air pressure which prevails in the airplane cabin at that particular moment and at that particular elevation. In other words, it is the negative pressure, point *d*, caused by the inhalation of the aviator, which produces the higher ambient pressure on the outside of the diaphragm for pushing the latter inwardly and to thereby fold the toggle levers rearwardly so that the toggle levers are moved rearwardly past the dead center 64 and the main oxygen inlet valve 58 is opened. Upon tilting this main valve 58 into an open position, the auxiliary oxygen inlet valve 149 is also tilted into an open position so that oxygen for subsequent inhalation is simultaneously admitted by these two valves into the respiration chamber. After these two valves 58, 149 have been snapped into their open or inhalation positions the diaphragm continues to collapse until its leg 77 strikes the back wall 46 of the casing.

Neither the extent of inward movement of the diaphragm and its leg 77, nor the consequent backward folding action of the toggle levers are of themselves important after the main and auxiliary oxygen inlet valves 58, 149 have been opened, but the diaphragm is immediately subjected to increasing pressure on its inner side by the incoming oxygen under pressure and the toggle levers are immediately subjected to an increasing pressure tending to move them outwardly to and past the dead center 64 into an outwardly folded position and again close the main and auxiliary oxygen inlet valves. With the inner end of the diaphragm leg 77 in contact with the casing back it will be obvious that the position of the lower toggle lever 62, 63, 67 will determine the leverage exerted by the diaphragm upon the upper toggle lever 68, 69, 70 and the tension of the toggle spring 71 and the effect of the latter in opposing the outward or expanding movement of the diaphragm. The inward or rearward movement of the main toggle levers is controlled by the adjustable stop screw 72 thereby determining how high the pressure in the respiration chamber 48 and the mask will go before the diaphragm trips the toggle mechanism and closes the main and auxiliary oxygen inlet valves 58, 149.

Upon inhalation, while oxygen is forced into the aviator's lungs under pressure, and while the aviator is flying up to an altitude of 25,000 feet the rising pressure curve is represented at *e* in graph Fig. 8 while *b* indicates the point at which the toggle mechanism operates the valves 58, 149 to cut off the supply of oxygen to the respiration chamber.

It is to be understood that if the pressure on

line *e* rises to point *f* which is below *b*, and if at this point of pressure *f* the aviator starts to exhale, this action will cause the pressure in the mask to first rise to point *g*, and then the toggle mechanism will be tripped and cut off the supply of oxygen. Thus the aviator has almost complete control of his breathing cycle. On inhalation he cannot prevent building up of pressure in the mask and respiration chamber but he can start exhaling any time he desires and the fact that a negative pressure is required at *d* before the main oxygen valve 58 is opened shows that the apparatus is not automatic as to the starting of the inhalation cycle, and thus prevents "over-ventilation" as previously explained. This negative pressure from ground level up to an altitude of 30,000 feet is due to so adjusting the spring 80 that at the time the oxygen inlet valves 48, 149 are open this spring 80 is not under tension and does not exert any pressure whatsoever and therefore is unable to move the toggle mechanism for shutting off the supply of oxygen. The pressure to effect closing of the oxygen inlet valves 58, 149 is due to the negative pressure caused by the aviator starting to inhale at point *h* as indicated in Fig. 8. The toggle spring 71 becomes active as the diaphragm moves outwardly so that the toggle mechanism closes the oxygen inlet valves and places the spring 80 under tension preparatory to assisting in again opening the oxygen inlet valves.

Up to an altitude of 30,000 feet the minimum pressure is controlled by the adjusting screw 74 which limits the movement of the toggle mechanism in the direction for closing the main and auxiliary oxygen inlet valves. It will be obvious that when the diaphragm is in its outward or expanded position the toggle spring 71 is in its most effective position to resist the inward contracting movement of the diaphragm and folding movement of the toggle levers. It therefore follows that this screw determines how low the pressure in the respiration chamber and mask can drop before the diaphragm can snap the toggle mechanism for moving the oxygen inlet valves into an open position, which in the present case is assumed to occur at an elevation of 30,000 feet.

It is true that the more the toggle levers are folded the weaker becomes the spring 71 but this is more than off-set by the increased power of this spring when these levers are folded to a greater extent.

When the aviator reaches an altitude above 30,000 feet the aneroid 107 has expanded to such an extent that the lever 102 is pushed outwardly into contact with the adjusting screw 113 while the toggle mechanism is in a position in which the oxygen inlet valves are in their closed position. This causes the cantilever 112 of the toggle mechanism to be lifted off of the minimum pressure adjusting screw 72 and thus raises the minimum pressure from point *i* to point *j* as indicated on the graph Fig. 9, upon reaching an altitude of 37,000 feet. Dilution of the oxygen with air at such an elevation is therefore prevented and ensures having the pressure in the mask always above ambient pressure and thus prevent outside air from possibly leaking into the mask. Due to this positive minimum pressure the apparatus becomes completely automatic at an altitude of 30,000 feet so that if the aviator becomes unconscious and his lungs continue to collapse until the pressure in the mask drops to point *j* on the graph Fig. 9, which is the same as the minimum

pressure while the aviator is conscious as indicated at point *i* on this graph, it causes the toggle mechanism to be snapped for again inflating the aviator. As the main oxygen inlet valve 58 always close when the pressure in the respiration chamber reaches a certain maximum it will be apparent that this phase of the cycle of operations of the apparatus is also automatic but still is not entirely beyond the control of a conscious person.

The aneroid 116 engages the diaphragm disk 126 at an elevation of about 25,000 feet. At low altitudes and up to about this elevation the aneroid 116 is in a collapsed condition due to the ambient pressures at these levels, the collapsing of this aneroid being limited by engagement of its end heads, as shown in Fig. 4. At an elevation of 25,000 feet the ambient pressure has dropped sufficiently to cause this aneroid to expand and engage its buffer 120 with the bearing disk 126 on the outer side of the diaphragm so that greater pressure must be built up in the respiration chamber before the toggle mechanism is tripped by the inward movement of the diaphragm and stops the flow of oxygen into the respiration chamber.

In other words, the point *b* of the 25,000 foot curve shown on graph Fig. 8 is raised to point *k* upon reaching an altitude of 37,000 feet, as shown in graph Fig. 9. As the aviator reaches still higher altitudes, the curve of the ambient pressure increases relatively and at, say 50,000 feet altitude, the point on the curve corresponding to the altitude would reach point *l* shown in graph Fig. 10.

It is desirable, as previously explained, to have the points *ij*, above the zero or ambient line, as indicated in Fig. 9. Inasmuch, however, as too great a minimum positive pressure may cause excessive exertion on the part of the aviator during exhalation the outward movement of the aneroid lever 112 is limited by means of the adjustable stop screw nut 110 whereby this pressure is arrested at point *m*, as indicated in Fig. 10.

As the aviator ascends and the ambient pressure decreases the effective force of the compression spring 99 is increased by the aneroid 98, the heads 96, 97 of which remain in engagement with each other up to an altitude of 30,000 feet but separate thereafter so as to put increasing pressure on this spring until the aviator gets up to 45,000 feet, at which time the head 100 of the retaining screw 99 engages the spider 89 of the casing of this valve 94 and thus prevents the aneroid 98 from putting more pressure on the exhalation valve 94. Above an altitude of 45,000 feet resistance to the opening of the exhalation valve 94 should increase and this extra resilience is obtained by the present means which are compact and do not require an undue amount of space in the apparatus.

As the aviator breathes rapid inhaling is possible but too rapid falling of the pressure in the mask is prevented in order to obtain the necessary osmotic action by the operation of the retarding valve 133, the position of which is controlled by the operation of the bellows 137, the metal check valve 105 and the auxiliary oxygen supply valve 149, as previously explained. As a result of the operation of this control mechanism the pressure curves do not drop sharply from the points *bkl* but continue in a more or less level fashion to points *nop* before falling off, as shown in Figs. 8, 9 and 10.

To compensate for the lower ambient pressure

at relatively high elevations all the maximum pressure points *bkl* are raised due to the operation of the aneroid 116, and the exhalation pressure points *cqr* are raised by the operation of the aneroid 98, but at extremely high altitudes, say, 45,000 feet, further expansion movement of the aneroid 98 is prevented by the head 100 striking the spider 89.

It is to be noted in this connection that the leakage through the metered hole 156 in the check valve 155 must be sufficient to allow the required flow of oxygen from the auxiliary valve chamber 141 through the capillary tube 146 to the bellows 137. The apparatus is therefore tested for different sizes of holes 156 until the exact diameter is obtained which gives the desired results and then this diameter is maintained within close tolerances, so that in effect this orifice 156 is adjustable but has a fixed setting after the required size has been determined.

In the preferred organization of this apparatus the opening of the auxiliary oxygen inlet valve 149 and the opening of the main oxygen inlet valve 58 are so timed that the opening of these valves occurs at the same time, as shown in Fig. 4, and the closing of the same is effected in like manner. This allows the auxiliary valve chamber 141 to have the same low pressure as the respiration chamber 48 and hence allows the control spring 139 of the mask to collapse the bellows 137 and force its contents past the check valve 156 and out into the diaphragm chamber 48. However, when the person starts to exhale, he raises the pressure in this respiration chamber 48, forces the diaphragm out, and causes the toggles to fold outwardly, thus closing both the main and auxiliary tilt valves 58 and 149. The closing of the auxiliary tilt valve 149 causes the relatively high pressure oxygen in the capillary tube 144 to fill the auxiliary valve chamber 141. This pressure will pass through the metered hole 156 and expand the bellows 137 in the mask against the resistance of its compression spring 139 and thus open the control valve 133 to its fully open position to permit of free exhalation. The metered hole 156, however, restrains this movement at the start of the exhalation, so that the aviator is prevented from exhaling freely until a certain interval of time has elapsed. In other words, the lungs are kept inflated for a longer period of time than would be the case if the orifice 156 were larger and the bores of the flexible tubes 144 and 146 larger. This means that the crests of all of the waves of Figs. 8, 9 and 10 are caused to be relatively wide (flattened) at their tops, instead of having sharp points. It will be clear now that the mechanism which includes the auxiliary oxygen inlet valve 149, the control valve 133 and the tubes 144 and 146 connecting the auxiliary inlet chamber 141 with the main oxygen supply chamber 52 and the bellows 137, respectively, will cause this apparatus to so function that when a person has inhaled as much of the air, or oxygen, or air-oxygen mix as he desires he will be prevented from starting to exhale at too rapid a rate, because it takes a certain length of time for the oxygen to pass through the capillaries of the lungs into the blood, and, at the same time, for the carbon dioxide to pass through these capillaries into the interior of the lungs. It is desirable therefore that when the lungs have been subjected to the maximum pressure of any particular inhalation that he be forced to hold the lungs at approximately that pressure for a fraction of a second before he is allowed to exhale freely. Although both

the main oxygen inlet valve 58 and the auxiliary oxygen inlet valve are operatively connected with the diaphragm through the medium of the toggle mechanism and associated parts, it is to be understood that any other suitable means may be employed for more directly transmitting the movement of this diaphragm to said valves for actuating them relative to the other parts with which they are associated in accordance with this invention.

The breathing apparatus shown in Figs. 11-17 is an organization which embodies this invention in a simplified form for use at ground level or low altitude by persons who may be either conscious or unconscious for therapeutic treatment of pulmonary edema which is caused by war gases or like ailments. Victims of war gases are usually not unconscious, hence the apparatus does not require an aneroid similar to the aneroid 107 and associated mechanism to change the minimum in the apparatus from negative to positive, nor are any of the other aneroid mechanisms required which cause the apparatus to function properly at different altitudes. In actual practice the apparatus shown in Figs. 11-17 ordinarily functions on a negative minimum pressure on patients who are conscious and exerts a negative pressure similar to the curve indicated on the graph or chart Fig. 12 for an altitude up to 25,000 feet before he will be inflated with oxygen by positive pressure. If desired the apparatus shown in Figs. 11-17 may be set to take care of unconscious persons in the manner indicated by the graph in Fig. 13.

In these figures no mechanism is employed outside of the diaphragm for increasing the expanding action of the diaphragm. The construction and operation of the toggle mechanism and the means for actuating the main oxygen inlet valve 58 are the same as those shown in Figs. 3, 4 and 7, with the following exception, and the same description and reference characters, so far as they apply, will not be repeated. Instead of employing the screw 82 shown in Fig. 4 for adjusting the tension of the spring 80, this is accomplished in the construction shown in Figs. 14, 15 and 16 by a cantilever spring arm 200 of angular form which has its low fixed end secured to the back wall 46 of the respiration chamber 48 by a bolt 201 while its elevated free end is connected with the inner or front end of the tension spring 202, and an adjusting screw 203 which turns in the back wall 46 and bears with its head against the outside of the latter while the threaded inner end of this screw engages with a threaded opening in the spring arm 200 between the ends thereof. By turning the screw 203 the spring 202 may be adjusted so that the same is under no tension when the parts are in a position if an inhalation cycle is to be started by a negative or suction pressure on the part of the patient under treatment.

Instead of arranging the exhalation valve 94 and its aneroid mechanism on the inner side of the mask, as shown in Fig. 6, this valve and its aneroid mechanism may be arranged outside of the mask, as shown in Fig. 17. In this last mentioned figure the exhalation valve 204 is movable toward and from a seat 205 on the front side of the housing 206 which encloses the aneroid 137 associated with the valve 133. The exhalation valve 204 surrounds ports 207 in the outer wall 208 of the chamber 130 and is guided in its movements by a guide pin 209 secured to the wall 208 and passing through a guide hole in the cen-

ter of the valve 204. The latter is yieldingly held in engagement with the seat 205 by a spring 210 surrounding this guide pin and bearing with its opposite ends against the outer side of this valve and an adjustable screw nut 211 working on the threaded outer end of the pin 209. Upon turning the screw nut 211 the resistance of the spring 210 to the opening of the valve 204 when subjected to the exhalation pressure of the patient may be regulated.

In the construction of the retarding mechanism shown in Fig. 14 no check valve device is utilized between the interior of the valve chamber 141 and the lower end of the conduit 146 such as is employed in the construction shown in Fig. 3.

The operation of the apparatus shown in Figs. 11-17 operates in substantially the same manner as that shown in Figs. 1-10. The fluid which it feeds to a person is however not confined to oxygen and in its stead any other gaseous fluid may be administered by the same to a person, such as carbon dioxide or medicated air, to suit the therapeutic requirements of the person being treated.

Inasmuch as the instrument shown in Figs. 11-17 is intended for use in hospitals, at ground level and lower altitudes, the graphs shown in Figs. 12 and 13 and indicating the operation of the same are confined to these levels and as the same correspond to the graphs shown in Figs. 2 and 9 relating to the operation at ground level or lower altitudes of the instrument shown in Figs. 1-7, the same description and identifying characters refer to both forms of this invention so far as they apply.

When the check valve 155, shown in Fig. 3, is omitted from the auxiliary valve chamber 141, as shown in Fig. 14, the flexible tube 146 is made sufficiently small in diameter so that the flow of oxygen through the same into the bellows 137 is sufficiently retarded by the frictional resistance within this tube to effect too rapid opening of the control valve 133.

It will be noted that in Figs. 14, 15, and 16 the pin 81 and the lug 152 are reversed on the upper and lower toggle levers of the toggle mechanism as compared with the showing in Figs. 3, 4 and 7, to suit the changed location of the parts with which they cooperate without however changing the function of the same.

I claim as my invention.

1. A breathing apparatus comprising a respiration chamber having an inlet adapted to be connected with a supply of oxygen under pressure and an outlet adapted to be connected with the breathing system of a person, valve means for opening and closing said inlet, and control means for controlling the opening of said valve means for increasing the maximum pressure at which the lungs of said person are inflated in proportion to the altitude where the apparatus is used including a diaphragm which is operatively associated with said valve means, an aneroid device which is inactive relative to said diaphragm in lower altitudes but operates in higher altitudes to resist the expansion of said diaphragm, and yielding buffer means interposed between said diaphragm and said aneroid device.

2. A breathing apparatus comprising a respiration chamber having an inlet adapted to be connected with a supply of oxygen under pressure and an outlet adapted to be connected with the breathing system of a person, valve means for opening and closing said inlet, and control means

for controlling the opening of said valve means for increasing the maximum pressure at which the lungs of said person are inflated in proportion to the altitude where the apparatus is used including a diaphragm which is expanded by pressure of oxygen in said chamber, means operatively connecting said diaphragm and inlet valve means including a toggle snap action mechanism, and an aneroid device which includes a bellows body, a relatively stationary head connected with one end of said body, a movable head connected with the opposite end of said body, and yielding buffer means adapted to be interposed between said diaphragm and said movable head and including a guide arranged on said movable head, a buffer slidable on said guide and adapted to be engaged by said diaphragm, and a spring interposed between said buffer and movable head.

3. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under compression and an outlet, a mask communicating with said outlet and having an exhalation passage, main valve means controlling said inlet, and auxiliary valve means for controlling said exhalation passage including a movable control valve adapted to control said exhalation passage, an auxiliary chamber having an auxiliary port leading to said respiration chamber, an auxiliary valve controlling said auxiliary port, pressure responsive means communicating with said auxiliary chamber and actuating said control valve, and actuating means responsive to rising and falling pressure in said respiration chamber and operatively connected with said main and auxiliary valves for opening the same when the pressure in said respiration chamber rises to a predetermined point.

4. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under compression and an outlet, a mask communicating with said outlet and having an exhalation passage, main valve means controlling said inlet, and auxiliary valve means for controlling said exhalation passage including a movable control valve adapted to control said exhalation passage, an auxiliary chamber having an auxiliary port leading to said respiration chamber, an auxiliary valve controlling said auxiliary port, pressure responsive means communicating with said auxiliary chamber and actuating said control valve, and actuating means responsive to rising and falling pressure in said respiration chamber and operatively connected with said main and auxiliary valves for opening the same when the pressure in said respiration chamber rises to a predetermined point and said actuating means being timed to open said auxiliary valve in advance of the opening of said main valve.

5. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under compression and an outlet, a mask communicating with said outlet and having an exhalation passage, main valve means controlling said inlet, and auxiliary valve means for controlling said exhalation passage including a movable control valve adapted to control said exhalation passage, an auxiliary chamber having an auxiliary port leading to said respiration chamber, an auxiliary valve controlling said auxiliary port, pressure responsive means communicating with said auxiliary chamber and actuating said control valve, actuating means responsive to rising and falling pressure in said respiration chamber and operatively connected with said main and auxiliary

valves for opening the same when the pressure in said respiration chamber rises to a predetermined point, and a conduit which places said auxiliary chamber in communication with said oxygen supply source in advance of said main inlet valve.

6. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under compression and an outlet, a mask communicating with said outlet and having an exhalation passage, main valve means controlling said inlet, and auxiliary valve means for controlling said exhalation passage, including a movable control valve adapted to control said exhalation passage, an auxiliary chamber having an auxiliary port leading to said respiration chamber, an auxiliary valve controlling said auxiliary port, pressure responsive means communicating with said auxiliary chamber and actuating said control valve, actuating means responsive to rising and falling pressure in said respiration chamber and operatively connected with said main and auxiliary valves for opening the same when the pressure in said respiration chamber rises to a predetermined point, and a check valve arranged in the line of communication between said auxiliary chamber and said exhalation passage and opening toward said auxiliary valve.

7. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under compression and an outlet, a mask communicating with said outlet and having an exhalation passage, main valve means controlling said inlet, and auxiliary valve means for controlling said exhalation passage including a movable control valve adapted to control said exhalation passage, an auxiliary chamber having an auxiliary port leading to said respiration chamber, an auxiliary valve controlling said auxiliary port, pressure responsive means communicating with said auxiliary chamber and actuating said control valve, actuating means responsive to rising and falling pressure in said respiration chamber and operatively connected with said main and auxiliary valves for opening the same when the pressure in said respiration chamber rises to a predetermined point, and a check valve arranged in the line of communication between said auxiliary chamber and said exhalation passage and opening toward said auxiliary valve and said check valve having a metered orifice.

8. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under compression and an outlet, a mask communicating with said outlet and having an exhalation passage, main valve means controlling said inlet, and auxiliary valve means for controlling said exhalation passage including a movable control valve adapted to control said exhalation passage, an auxiliary chamber having an auxiliary port leading to said respiration chamber, an auxiliary valve controlling said auxiliary port, pressure responsive means communicating with said auxiliary chamber and actuating said control valve, actuating means responsive to rising and falling pressure in said respiration chamber and operatively connected with said main and auxiliary valves for opening the same when the pressure in said respiration chamber rises to a predetermined point, and means for actuating said control valve including a bellows which is connected with said control valve and the interior of which communicates with said auxiliary chamber.

9. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under pressure and an outlet for oxygen, a main valve

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for controlling said inlet, a mask having a discharge passage for spent gas leading to the outer atmosphere, a conduit connecting said respiration chamber and mask, a control valve which controls said discharge passage, a bellows connected with said control valve, an auxiliary valve chamber adapted to be connected with and disconnected from said respiration chamber, and a tube connecting the interior of said auxiliary valve chamber with the interior of said bellows and having its major part arranged in said conduit and thereby preventing the same from being frozen.

10. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under pressure and an outlet for delivering oxygen to a person, an inlet valve for controlling said inlet, a diaphragm responsive to the rise and fall of pressure in said chamber, motion transmitting means for causing said valve to open when said diaphragm is collapsed and to close said valve when the diaphragm is expanded including a toggle mechanism having two levers, the main one of which is operatively associated with said valve and the other operatively associated with said diaphragm, screw adjusting means for controlling the action of the main lever of said toggle mechanism for closing said valve, and screw adjusting means for controlling the action of the main lever of said toggle mechanism for opening said valve.

11. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under pressure and an outlet for delivering oxygen to a person, an inlet valve for controlling said inlet, a diaphragm responsive to the rise and fall of pressure in said chamber, motion transmitting means for causing said valve to open when said diaphragm is collapsed and to close said valve when the diaphragm is expanded including a toggle mechanism having two levers, the main one of which is operatively associated with said valve and the other operatively associated with said diaphragm, and an aneroid mechanism for controlling the operation of said valve including a control lever which is engaged by the main lever of said toggle mechanism, an aneroid engaging said control lever and adapted to reduce the closing of said valve in higher altitudes, and adjustable means for limiting the movement of the control lever under the action of said aneroid.

12. A breathing apparatus comprising a respiration chamber having an inlet for oxygen under pressure and an outlet for delivering oxygen to a person, an inlet valve for controlling said inlet, a diaphragm responsive to the rise and fall of pressure in said chamber, motion transmitting means for causing said valve to open when said diaphragm is collapsed and to close said valve when the diaphragm is expanded including a toggle mechanism having two levers, the main one of which is operatively associated with said valve and the other operatively associated with said diaphragm, and an aneroid mechanism for controlling the operation of said valve including a control lever which is engaged by the main lever of said toggle mechanism, an aneroid engaging said control lever and adapted to reduce the closing of said valve in higher altitudes, adjustable means for limiting the movement of the control lever under the action of said aneroid, and spring means for moving said control lever in a direction opposite to that which it is moved by said aneroid.

13. A breathing apparatus comprising a respi-

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ration chamber having a valve controlled inlet for oxygen under pressure, a mask communicating with said chamber and having an exhalation passage leading to the outer atmosphere and a valve seat associated with said passage, an exhalation valve movable relative to said seat for opening and closing said passage, an aneroid device which is responsive to altitude and which operates to increase the resistance to the opening of said exhalation valve in proportion to the increase in altitude where the apparatus is used, a main inlet valve for controlling said inlet, a main outlet valve for controlling said exhalation passage, and a diaphragm which is responsive to variations in pressure in said respiration chamber and which is operatively associated with both said main inlet valve and said main outlet valve and actuates said main inlet and outlet valves in unison independently of said aneroid operated exhalation valve.

14. A breathing apparatus comprising a respiration chamber having a valve controlled inlet for oxygen under pressure, a mask communicating with said chamber and having an exhalation passage leading to the outer atmosphere and a valve seat associated with said passage, an exhalation valve movable relative to said seat for opening and closing said passage, an aneroid device which is responsive to altitude and which operates to increase the resistance to the opening of said exhalation valve in proportion to the increase in altitude where the apparatus is used and which is provided with means for rendering said aneroid device ineffective below a predetermined altitude, a main inlet valve for controlling said inlet, a main outlet valve for controlling said exhalation passage, and a diaphragm which is responsive to variations in pressure in said respiration chamber and which is operatively associated with both said main inlet valve and said main outlet valve and actuates said main inlet and outlet valves in unison independently of said aneroid operated exhalation valve.

15. A breathing apparatus comprising a respiration chamber having a valve controlled inlet for oxygen under pressure, a mask communicating with said chamber and having an exhalation passage leading to the outer atmosphere and a valve seat associated with said passage, an exhalation valve movable relative to said seat for opening and closing said passage, an aneroid which is arranged axially in line with said exhalation valve and which expands and contracts in accordance with the altitude in which the apparatus is located, means whereby said valve is yieldingly mounted on said aneroid and moved toward and from said seat, a main inlet valve for controlling said inlet, a main outlet valve for controlling said exhalation passage, and a diaphragm which is responsive to variations in pressure in said respiration chamber and which is operatively associated with both said main inlet valve and said main outlet valve and actuates said main inlet and outlet valves in unison independently of said aneroid operated exhalation valve.

16. A breathing apparatus comprising a respiration chamber having a valve controlled inlet for oxygen under pressure, a mask communicating with said chamber and having an exhalation passage leading to the outer atmosphere and a valve seat associated with said passage, an exhalation valve movable relative to said seat for opening and closing said passage, an aneroid

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which is arranged axially in line with said exhalation valve and which is responsive to the ambient atmospheric pressure, yielding means whereby said valve is mounted on said aneroid and said valve is capable of being opened by the exhalation of the person wearing the mask independently of said aneroid, a main inlet valve for controlling said inlet, a main outlet valve for controlling said exhalation passage, and a diaphragm which is responsive to variations in pressure in said respiration chamber and which is operatively associated with both said main inlet valve and said main outlet valve and actuates said main inlet and outlet valves in unison independently of said aneroid operated exhalation valve.

17. A breathing apparatus comprising a respiration chamber having a valve controlled inlet for oxygen under pressure, a mask communicating with said chamber and having an exhalation passage leading to the outer atmosphere and a valve seat associated with said passage, an exhalation valve movable relative to said seat for opening and closing said passage, an aneroid which is arranged axially in line with said exhalation valve and which is responsive to the ambient atmospheric pressure, yielding means whereby said valve is mounted on said aneroid and said valve is capable of being opened by the exhalation of the person wearing the mask independently of said aneroid, stop means including a projection arranged centrally on the front side of said aneroid and adapted to engage an adjacent wall of the mask for limiting the movement of the aneroid toward said valve seat and the resistance to the opening of said valve, a main inlet valve for controlling said inlet, a main outlet valve for controlling said exhalation passage, and a diaphragm which is responsive to variations in pressure in said respiration chamber and which is operatively associated with both said main inlet valve and said main outlet valve and actuates said main inlet and outlet valves in unison independently of said aneroid operated exhalation valve.

18. A breathing apparatus comprising a respiration chamber having a valved inlet for oxygen under pressure, a mask communicating with said respiration chamber and to be worn by a person, and means for controlling exhalation from said mask including an exhalation chamber mounted on the inner side of said mask and provided with an exhalation passage and an outwardly facing valve seat around said passage, an exhalation valve movable toward and from said seat, an aneroid mounted on the interior of said chamber, a spring interposed between said valve and said aneroid, a guide pin which is mounted on said aneroid and carries said valve and spring and is provided with a stop which limits the movement of the valve away from the aneroid, and stop means whereby the movement of said aneroid independently of said valve is limited after the valve engages said seat.

19. A breathing apparatus comprising a respiration chamber having a valved inlet for the admission of oxygen under pressure, a mask communicating with said chamber, an exhalation passage, an exhalation valve which opens said exhalation passage by exhalation of the person wearing the mask, a control valve device which modifies the action of the exhalation valve, and means for closing the control valve slowly at the start of an exhalation cycle.

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20. A breathing apparatus comprising a respiration chamber having a valved inlet for admitting oxygen under pressure, a mask communicating with said chamber and having an exhalation passage which is provided with an outwardly facing exhalation valve seat and an inwardly facing control valve seat, an exhalation valve movable toward and from the exhalation valve seat, a control valve movable toward and from said control valve seat, and means for instantly closing the control valve and preventing gas from leaking past the exhalation valve should the pressure in the mask become higher than that which would open said exhalation valve independently of the control valve.

21. A breathing apparatus comprising a respiration chamber having a valved inlet for the admission of oxygen under pressure, a mask communicating with said chamber and having an exhalation passage leading from the interior thereof to the outer atmosphere, an exhalation valve device arranged within the mask which is opened by exhalation of the wearer through said passage and is arranged close to the wearer's face and thereby prevented from becoming inoperative by freezing, a control valve device which is arranged on the exterior of the mask and controls the exhalation through said passage, and means for actuating said control valve device which are of greater power than the means which actuate the exhalation valve device and prevent freezing of the control valve device.

22. A breathing apparatus comprising a respiration chamber having a comparatively large gas inlet, a valve for controlling said inlet, a gas supply conduit having a comparatively large delivery part connected with said inlet, a comparatively large receiving part adapted to receive gas under pressure, and a narrow part intermediate said receiving and delivery parts and operating to prevent surges of gas passing through said conduit, an auxiliary valve device having an auxiliary chamber having an inlet communicating with the large delivery part of said conduit and an outlet communicating with said respiration chamber, and an auxiliary valve which controls the outlet of said auxiliary chamber, a diaphragm forming a wall of said respiration chamber and movable in response to rising and falling of pressure in said respiration chamber, and means for operating said valves by motion derived from said diaphragm.

23. A breathing apparatus comprising a respiration chamber having a comparatively large gas inlet, a valve for controlling said inlet, a gas supply conduit having a comparatively large delivery part connected with said inlet, a comparatively large receiving part adapted to receive gas under pressure, and a narrow part intermediate said receiving and delivery parts and operating to prevent surges of gas passing through said conduit, an auxiliary valve device having an auxiliary chamber having an inlet communicating with the large delivery part of said conduit and an outlet communicating with said respiration chamber, and an auxiliary valve which controls the outlet of said auxiliary chamber, a diaphragm forming a wall of said respiration chamber and movable in response to rising and falling of pressure in said respiration chamber, and means for operating said valves by motion derived from said diaphragm including a toggle mechanism having toggle levers one of which is operatively connected with said diaphragm and the other connected with said valves.

24. A breathing apparatus comprising a respiration chamber having a comparatively large gas inlet, a valve for controlling said inlet, a gas supply conduit having a comparatively large delivery part connected with said inlet, a comparatively large receiving part adapted to receive gas under pressure, and a narrow part intermediate said receiving and delivery parts and operating to prevent surges of gas passing through said conduit, an auxiliary valve device having an auxiliary chamber having an inlet communicating with the large delivery part of said conduit and an outlet communicating with said respiration chamber, and an auxiliary valve which controls the outlet of said auxiliary chamber, a diaphragm forming a wall of said respiration chamber and movable in response to rising and falling of pressure in said respiration chamber, and means for operating said valves by motion derived from said diaphragm including a toggle mechanism having toggle levers one of which is operatively connected with said diaphragm and the other connected with said valves, and means for adjusting the throw of the toggle lever which is connected with said valves.

25. A breathing apparatus comprising a respiration chamber having a main gas inlet, a mask communicating with said respiration chamber and having an outlet passage leading to the atmosphere, a main inlet valve for opening and closing said main inlet, a control valve for opening and closing said outlet passage, a gas supply conduit connected with said main inlet, an auxiliary valve device having an auxiliary valve chamber which is adapted to communicate with said conduit and said respiration chamber and an auxiliary valve for controlling the flow of gas through said auxiliary chamber, and means for actuating said control valve by gas pressure derived from said auxiliary chamber.

26. A breathing apparatus comprising a respiration chamber having a main gas inlet, a mask communicating with said respiration chamber and having an outlet passage leading to the atmosphere, a main inlet valve for opening and closing said main inlet, a control valve for opening and closing said outlet passage, a gas supply conduit connected with said main inlet, an auxiliary valve device having an auxiliary valve chamber which is adapted to communicate with said conduit and said respiration chamber and an auxiliary valve for controlling the flow of gas through said auxiliary chamber, and means for actuating said control valve by gas pressure derived from said auxiliary chamber including a bellows carrying said control valve and communicating with said auxiliary valve chamber.

27. A breathing apparatus comprising an indi-

vidual mask adapted to be worn by a single person, a respiration chamber communicating with said mask and having an inlet for oxygen, demand valve means for opening and closing said inlet, actuating means for operating said demand valve means including a diaphragm which forms a wall of said chamber and which is contracted and expanded in response to inhalation suction within the chamber and atmospheric pressure outside of this chamber, control means for permitting full expansion of said diaphragm at low altitudes and reduced expansion of the same at high altitudes including an aneroid having a relatively fixed end and a movable end, the expansion of the aneroid being limited so that the same in its fully expanded position in high altitudes will extend into the path of said diaphragm and arrest the expansion of the same and in the contracted condition of the aneroid in low altitudes its movable end will be out of the path of the diaphragm and permit the latter to expand fully, and stop means mounted on the movable end of said aneroid and adapted to limit the expansion of said diaphragm including a guide post connected with said movable end, a buffer slidable on said post and adapted to be engaged by said diaphragm, spring means for pushing said buffer toward said diaphragm, and stop means for limiting the extent of movement of said buffer toward said diaphragm on said post.

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